Extratropical Cyclones of the Western U.S.

Major Advances in Prediction and Understanding

Cliff Mass, Atmospheric Sciences

Columbus Day Storm, 1962: The steeple atop historic Campbell Hall, on the Oregon College of Education Campus, Monmouth.

Bottom Line

- Before roughly 1990 most West Coast extratropical cyclones were poorly forecast at any time range.
- After that time, the vast majority were well predicted.
- We now know vastly more about the structure of these storms.
- We know much more about their interactions with West Coast terrain.

The is a lot of talk about the *Perfect Storms* and *Storms of the Century* along the East Coast

- The truth is that the strongest West Coast storms are more intense and damaging.
- Big trees are major "force multipliers" for West Coast midlatitude cyclones.

Wimpy East Coast Trees

Serious West Coast Trees

Some Perspective

Native Americans knew about the great winter storms that struck the Pacific coast

… and had several legends regarding their origin.

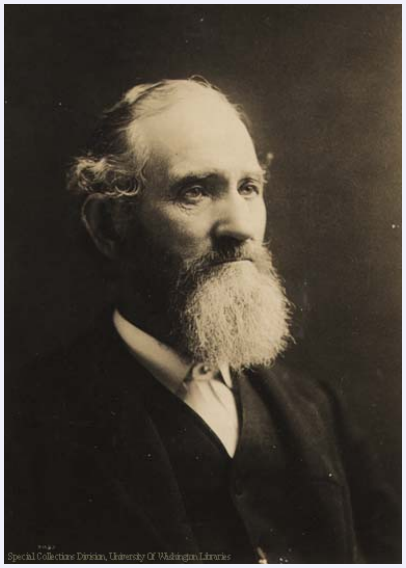
The Thunderbird

European explorers appreciated the threat

John Meares,1788, off of Cape Flattery of the Olympics Peninsula

"The force of southerly storms was evident to every eye; large and extensive woods being laid flat by their power, the branches forming one long line to the North West, intermingled with the roots of innumerable trees, which have been torn from their beds and helped to mark the furious course of their tempests."

Early settlers learned quickly about the impacts of the great Pacific cyclones



Arthur Denny

Seattle

January 9, 1880 Storm

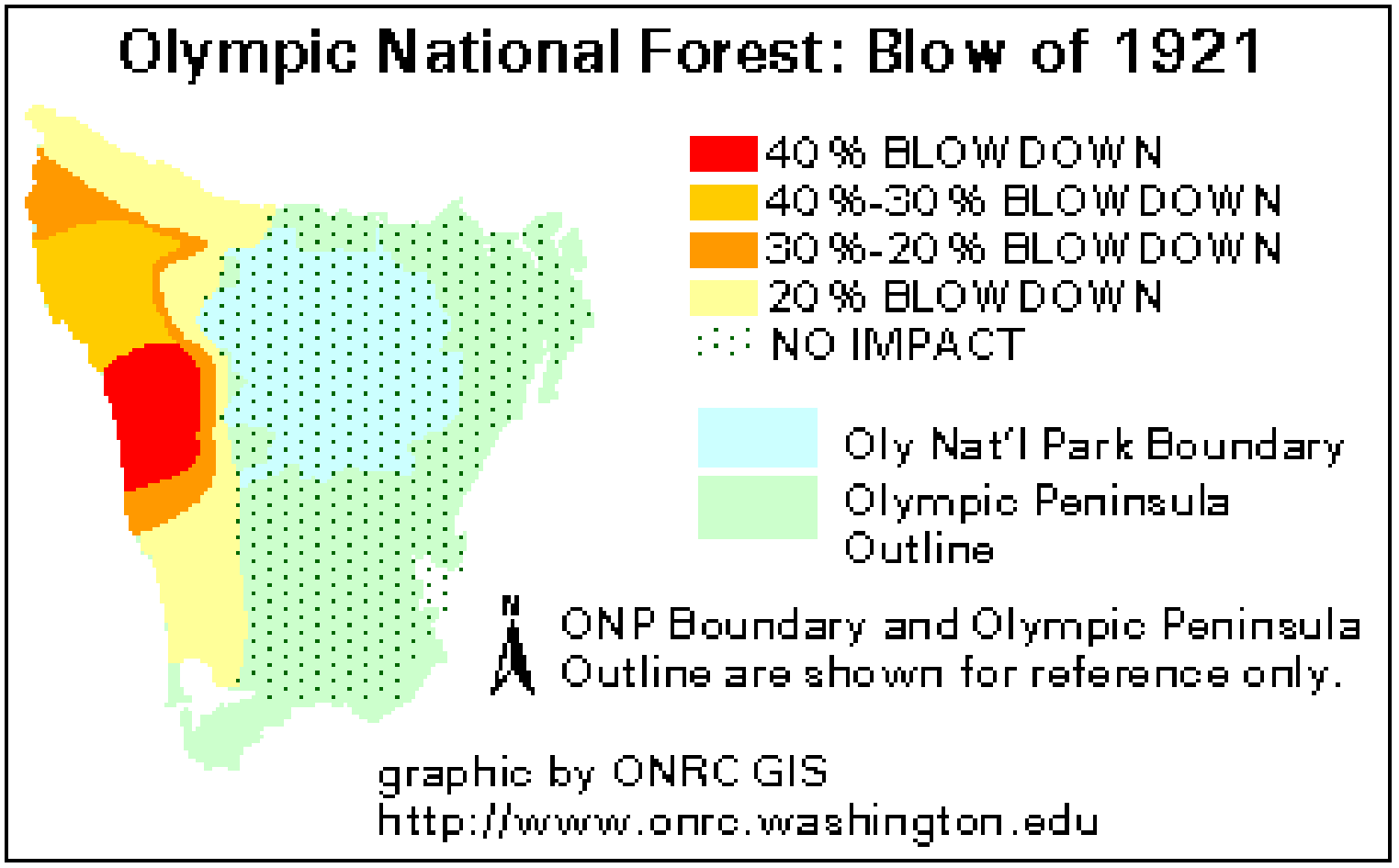
- Hit northern Oregon and southern Washington toppling tens of thousands of trees.
- Wind gusts were estimated to reach 138 mph on the coast and 70-80 mph in the interior.
- Buildings throughout the Willamette Valley, were damaged or destroyed. Part of the roof of the Oregon State Capital in Salem was blown off.

January 29, 1921

- **Hurricane-force winds struck the entire Washington Coast**
  - At North Head sustained winds reached 126 mph, with a maximum one-minute wind of 150 mph before the sensor failed.

  - At Tatoosh Island, 150 miles to the north, winds reached 110 mph.

In some areas over 40% of the trees were blown down



As a result, this event has become known as the

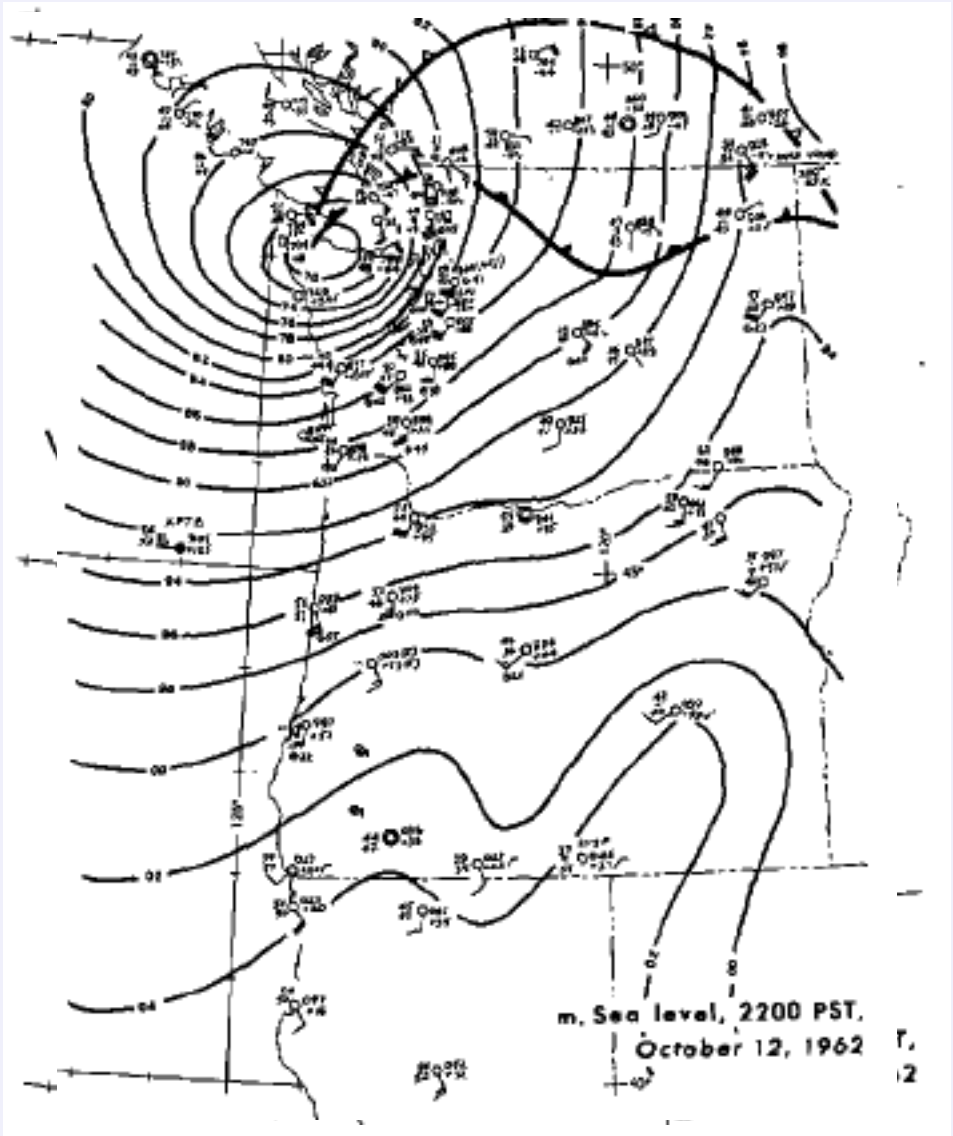
"The Olympic Blowdown Storm"

But these and other storms were overshadowed by the Columbus Day Storm: October 12, 1962

- **The strongest Pacific storm to strike the NW since the arrival of European settlers**
- **Probably the most powerful non-tropical cyclone to hit the lower-48 states in a century. Maybe more.**

Extraordinary Impact

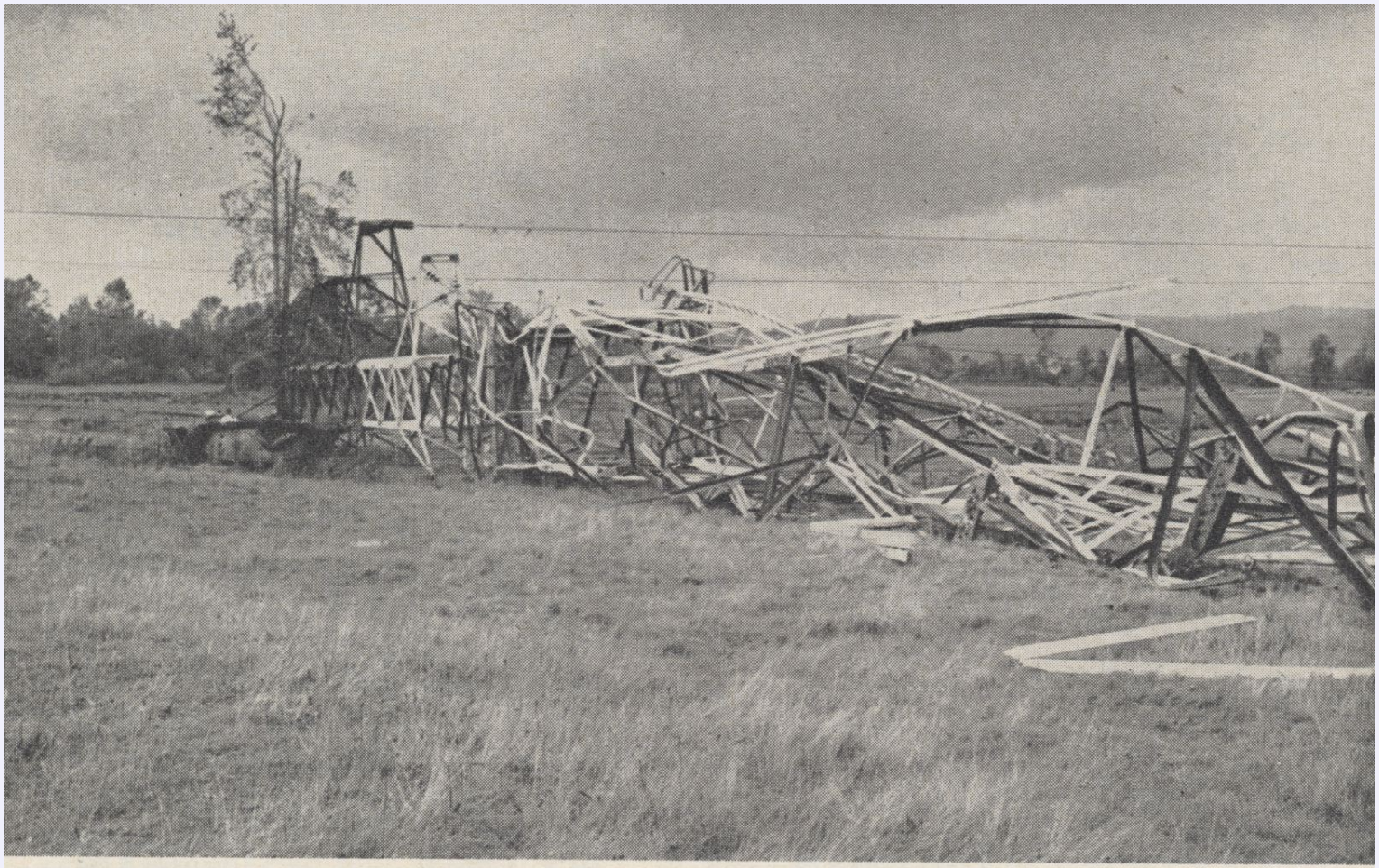
- An extensive area, stretching from northern California to southern British Columbia experienced hurricane-force winds, massive treefalls, and power outages.
- Sustained winds reaching 60-70 mph and gusts **over 120 mph**.
- In Oregon and Washington, 46 died and 317 required hospitalization.
- Flooding and landslides in northern California.
- 955 hPa low moved northward along the coast.



m. Sea level, 2200 PST,
October 12, 1962

Impacts

- Ten to 15 billion board feet of timber were downed, enough to build a million homes and far greater than the yearly output of the NW forest industry.
- 53,000 homes were damaged, thousands of utility poles were toppled, and the twin 520-ft steel towers that carried the main power lines of Portland were crumpled.



The toppled tower carrying 115,000-volt cables at Barlow Point, two miles west of Longview Bridge on the Columbia River. Bonneville Power Administration photo.

On the state capitol ground in Salem, Oregon, the bronze status, the Circuit Rider was toppled

Columbus Day 1962: At Cape Blanco estimated winds were 150 mph with gusts to 179!

Mt. Hebo Radar Facility:

Gusts exceeding 130 mph

Courtesy: Mark Cole

How good were the Weather Bureau Predictions for the Columbus Day Storm?

The Lead Up

- Forecasters in the Portland and Seattle offices of the Weather Bureau knew there was a fast-moving disturbance out there.
- But the position and amplitude were uncertain.
- The NWP models of the day were predicting a modest system making landfall south of Portland.

October 11th Forecast: No Storm on October 12th!

—A. P. wirephoto map.

The Seattle Times 51
Thursday, October 11, 1962

Wrangle Over State Capital Stirs Alaskans

(Wayne Jacobi, Times staff reporter, is with a Seattle Chamber of Commerce delegation attending the annual convention of the Alaska State Chamber o

Seattle Times

State Forecasts

Western Washington: Partly cloudy, with a few showers tonight and tomorrow. Snow on the mountain passes. High tomorrow, 46 to 54; low tonight, 35 to 45.

Mountain areas: Freezing level dropping to about 3,000 or 4,000 feet tonight and tomorrow, with rain changing to snow above 3,000 feet. Snow flurries on the east slopes of the Cascades.

Eastern Washington: Rain, beginning in the southwest, becoming general by tonight with increasing winds. Partly cloudy and cooler tomorrow, with snow flurries over the mountains. High tomorrow, 42 to 52; low tonight, 35 to 45.

Marine Warnings

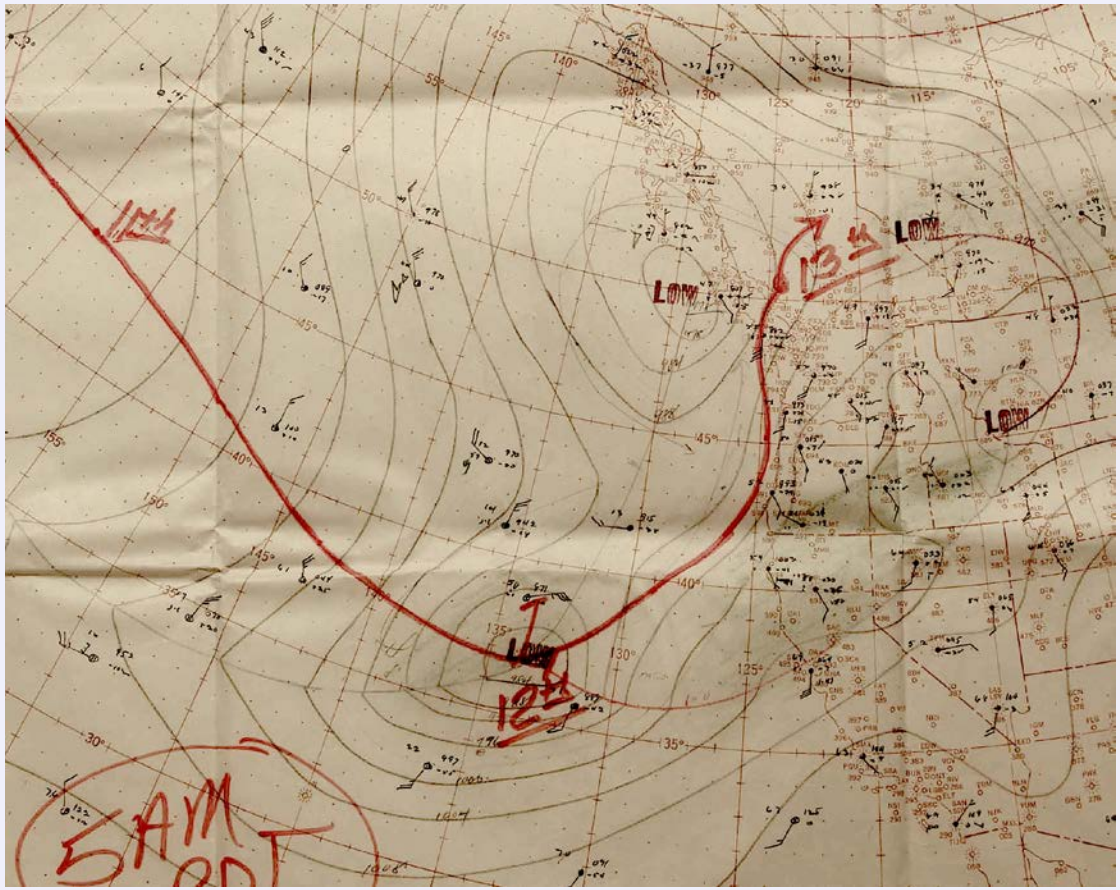
Gale warnings were hoisted on the following waters:

Inland—southeast winds 30 to 45 knots, diminishing tonight.

Strait—northeast winds 35 to 45 knots, shifting to southwest or west and diminishing tonight.

Whole-gale warnings were displayed on the coast from Tatoosh to Astoria for southeast winds 50 to 60 knots, diminishing to 34 to 46 tonight and 23 to 34 tomorrow.

As Weather Bureau forecasters analyzed the sparse data over the Pacific for the 5 AM October 12th chart, they realized that the storm was stronger and the threat to the West Coast was substantial



Jaw-dropping observations

- At 7 AM, the three-hourly reports from a series of radar picket ships off the coast started to come in.
- A ship at 40N, 130 W reported a pressure fall of 22.5 hPa in 3 hours with sustained southeast winds of 50 knots!
- Another picket ship had northwest winds at 80 knots (92 mph), a pressure of 962 hPa, and a pressure fall of 33 hPa in 3 hr.
- A Brazilian ship, 60 miles SW of Cape Blanco, 964 hPa, SE 85 mph

U.S.S Skywatcher

Forecasts were updated to predict a more dangerous storm—hours before it hit

ORTS FINAL

vents at Fair—3rd Section

Rained Out!

Rain and high winds today caused Ford Frick, commissioner of baseball, to postpone the sixth game of the World Series in San Francisco. It was rescheduled for tomorrow, starting at 11 o'clock, Seattle time. (Details, Page 14.)

— 'Very Dangerous' Winds —

New Storm Coming

A "very dangerous" new storm packing winds up to 75 miles an hour was moving up the Pacific Coast toward Washington today.

The Weather Bureau raised whole-gale warnings, calling for winds up to 75 miles an hour, for the Oregon and Washington coasts and the Strait of Juan de Fuca.

Small-craft warnings were raised to gale warnings over Puget Sound at 2 o'clock this afternoon. The warnings are for east winds increasing to 35-to-52 miles an hour and shifting to southeast this evening, then to southwest later tonight.

The Weather Bureau advised hunters not to select campsites near snags or trees in exposed places.

The main part of the storm—centered in the Pacific Ocean but moving northeast — was expected to be 100 miles off the mouth of the Columbia River this afternoon.

"Ship reports near this storm center indicate that it is a very dangerous storm," a Weather Bureau advisory said.

Rain, heavy at times, is forecast for Western Washington for the next 24 hours.

Chinook Pass reported at 2 o'clock that it was snowing hard. The mountain forecast was for rain, very heavy at times tonight, with snow above 4,000 feet. Showers of rain or snow are expected tomorrow.

The first damage reports as the storm moved up the coast were from Ashland, Ore., where sudden gusts knocked down 20 trees. Power in Ashland was out and roads were blocked.

A hangar at Ashland's airport, with a plane inside, was blown over.

High winds also were reported in the Brookings area on the Southern Oregon coast.

Winds up to 50 miles an hour kept six ships inside the harbor at Astoria overnight. The Columbia River lightship was blown two miles from its normal position.

(Damage was heavy in yesterday's storm. Page 2.)

The Seattle Daily Times

Telephone MAin 2-0300

Published Daily and Sunday and Entered as Second Class Matter at Seattle, Washington, Vol. 85, No. 285.

Fair Attendance: Yesterday—32,429; Total—8,822,519

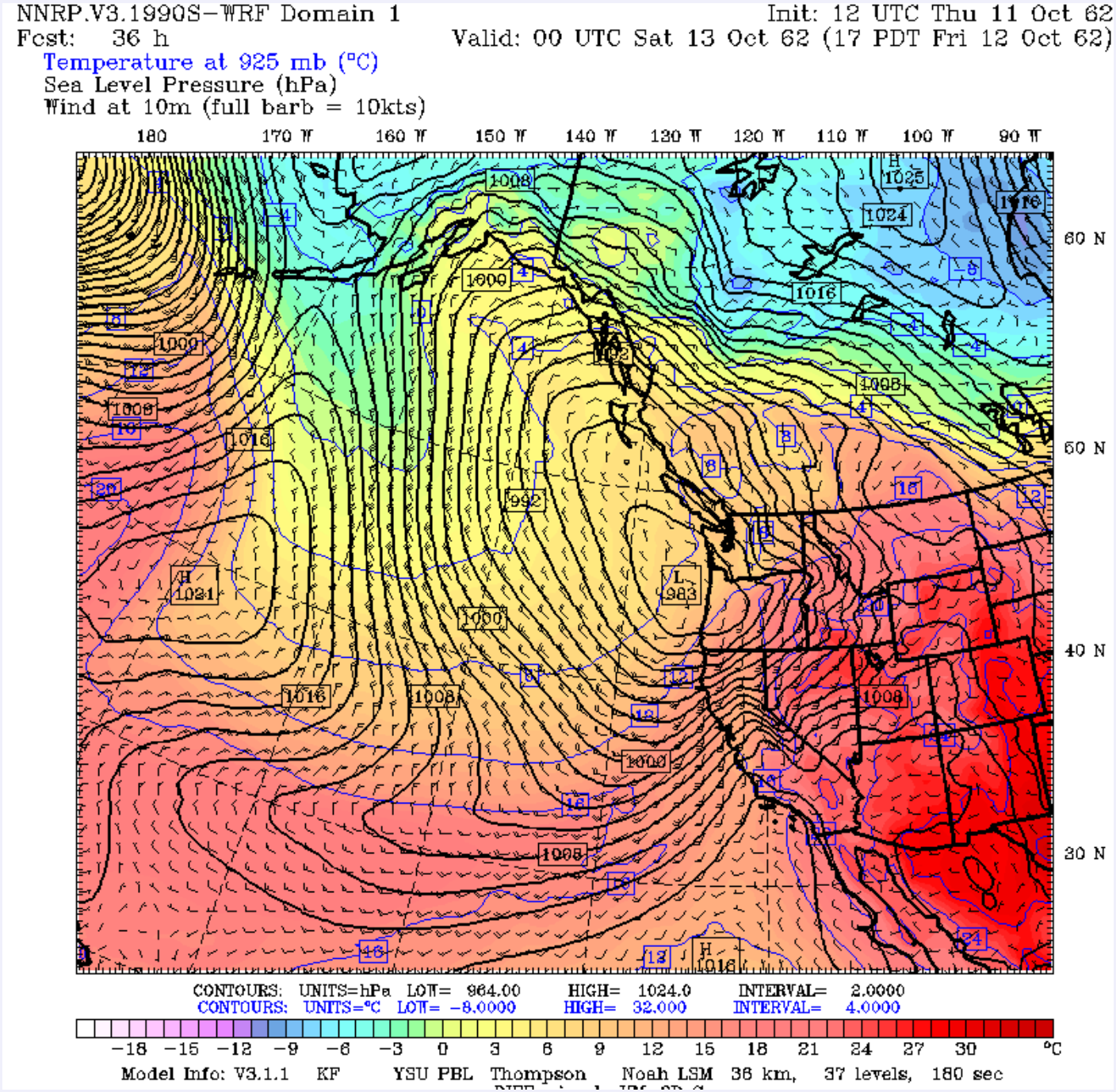
4 SECTIONS, 56 PAGES SEATTLE, WASHINGTON, FRIDAY, OCTOBER 12, 1962. Price 10c

Could a modern weather prediction model run at high resolution get the forecast right?

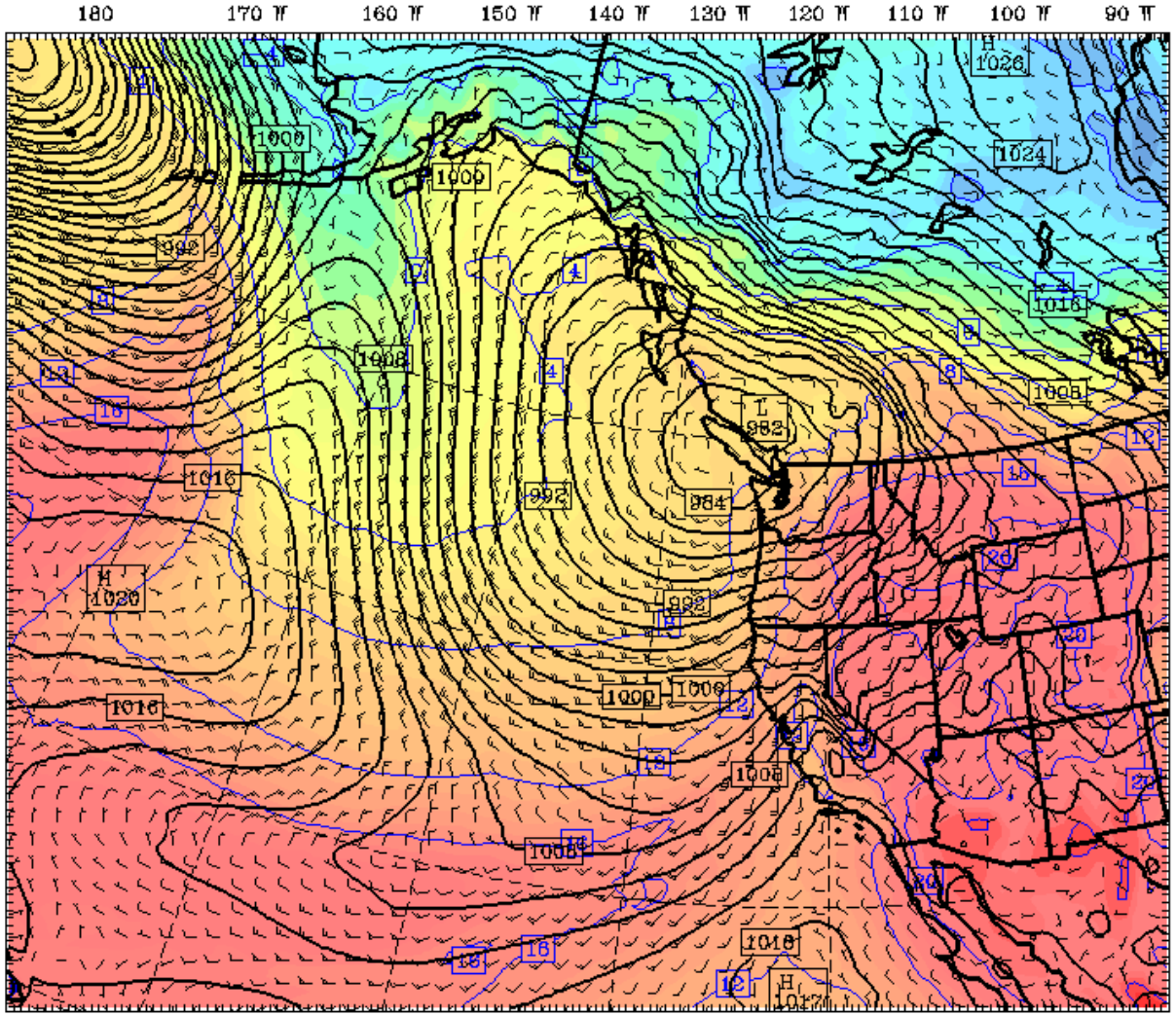
- Rick Steed, Research Scientist in the UW Atmospheric Sciences Department, ran the WRF model with full physics and high resolution.
- Initialized the model with the NCEP reanalysis grids.

The Answer: No

Consider a forecast begun the day before (October 11th) at 5 AM.

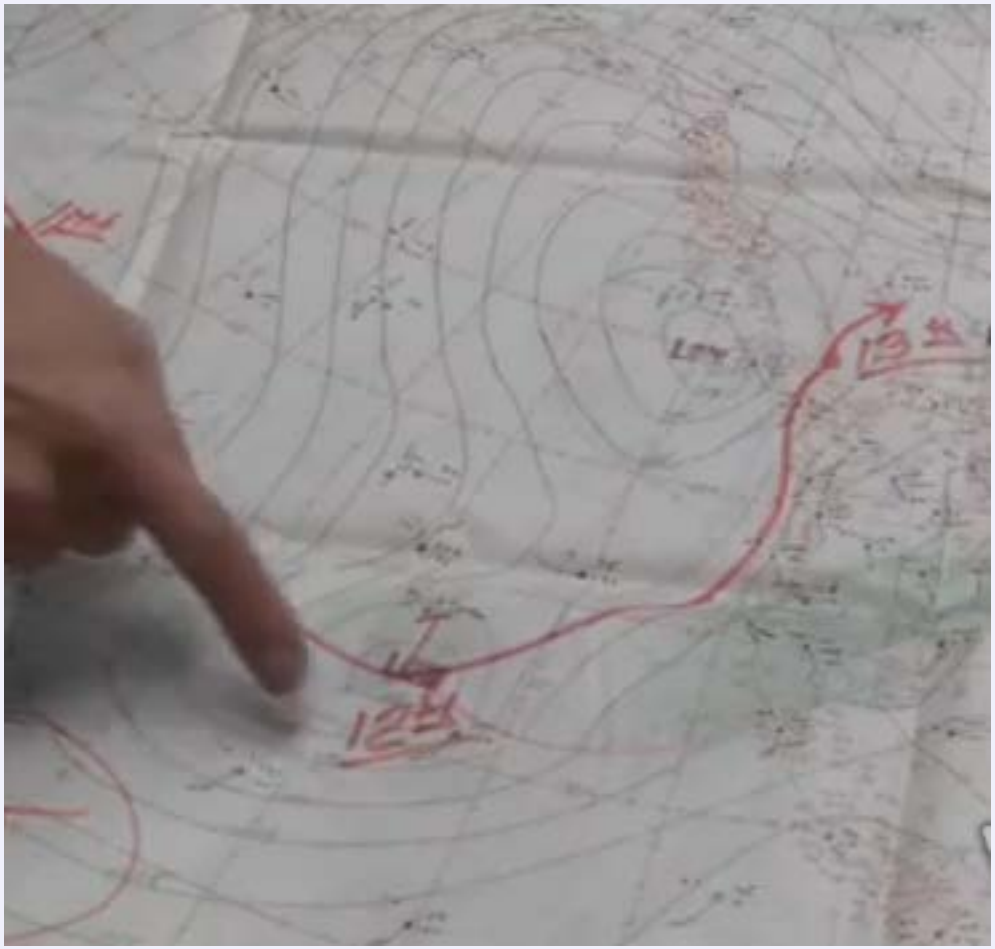

NNRP.V3.1990S-WRF Domain 1
Init: 12 UTC Thu 11 Oct 62
Fcst: 36 h
Valid: 00 UTC Sat 13 Oct 62 (17 PDT Fri 12 Oct 62)
Temperature at 925 mb (°C)
Sea Level Pressure (hPa)
Wind at 10m (full barb = 10kts)
180
170 W
160 W
150 W
140 W
130 W
120 W
110 W
100 W
90 W
60 N
50 N
40 N
30 N
H 1025
1024
1016
1008
1000
992
H 1021
L 983
H 1016
CONTOURS: UNITS=hPa LOW= 964.00 HIGH= 1024.0 INTERVAL= 2.0000
CONTOURS: UNITS=°C LOW= -8.0000 HIGH= 32.000 INTERVAL= 4.0000
-18 -15 -12 -9 -6 -3 0 3 6 9 12 15 18 21 24 27 30 °C
Model Info: V3.1.1 KF YSU PBL Thompson Noah LSM 36 km, 37 levels, 180 sec

NNRP.V3.1990S-WRF Domain 1 Init: 12 UTC Thu 11 Oct 62
Fcst: 42 h Valid: 06 UTC Sat 13 Oct 62 (23 PDT Fri 12 Oct 62)
Temperature at 925 mb (°C)
Sea Level Pressure (hPa)
Wind at 10m (full barb = 10kts)



The Problem?

- Lack of data and poor initializations
- Just a few ship reports offshore.

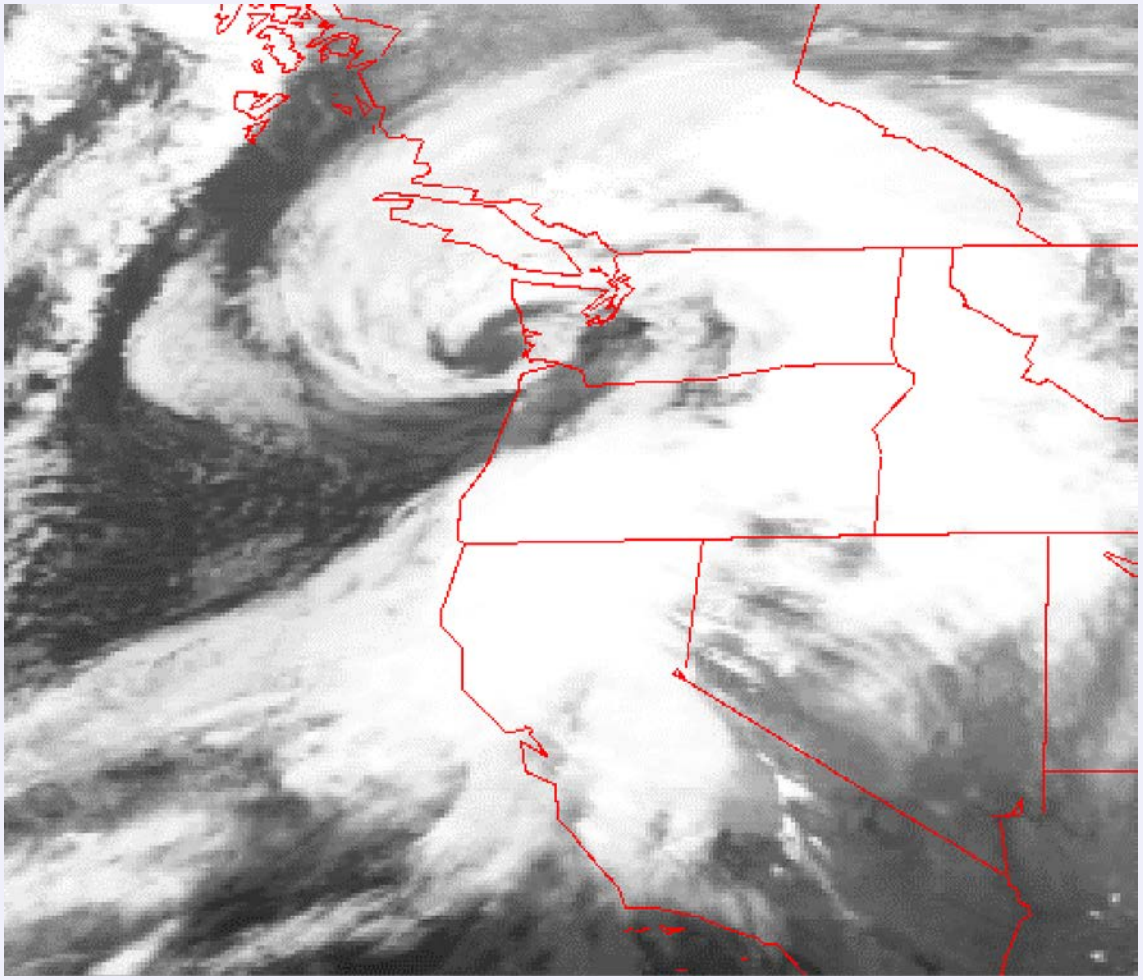


Major Cyclone Forecast Busts Continued Until Approximately 1990

- …**And then everything changed**, almost overnight
- Nearly every major midlatitude cyclone to hit the West Coast has been forecast with some skill up to several days ahead of time.
- Clearly, the advent of more extensive use of satellite data and better models has had impact.

The First Major Forecasting Triumph

Inauguration Day Storm January 20, 1993



The first major windstorm to be highly skillfully forecast….

But the media and public were not paying attention!

Inauguration Day Storm

- Winds of over 100 mph were observed at exposed sites in the coastal mountains and the Cascades, with speeds exceeding 80 mph along the coast and in the interior of western Washington.
- In Washington State six people died, approximately 870,000 customers lost power, 79 homes and 4 apartment buildings were destroyed, 581 dwellings sustained major damage.

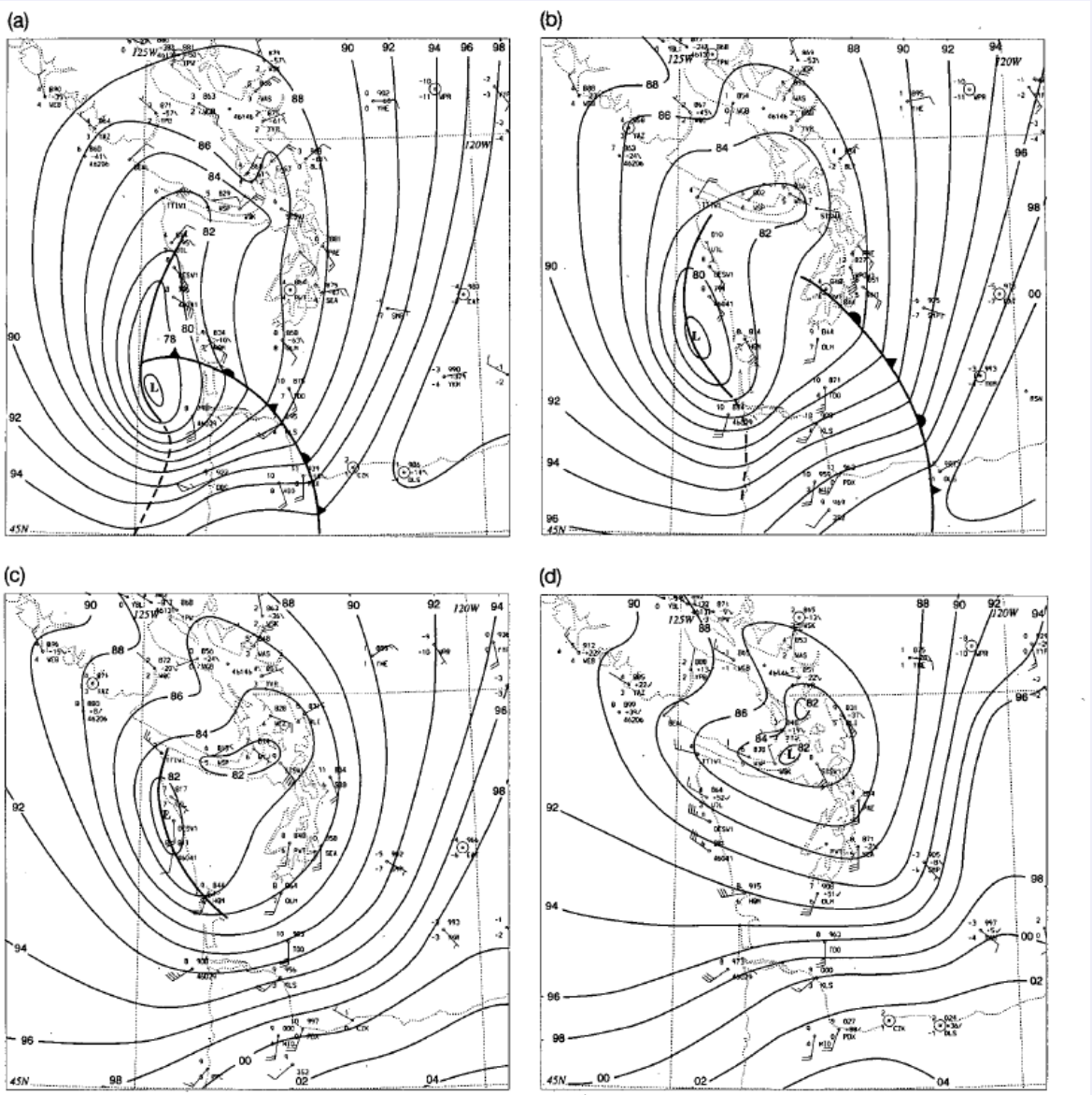


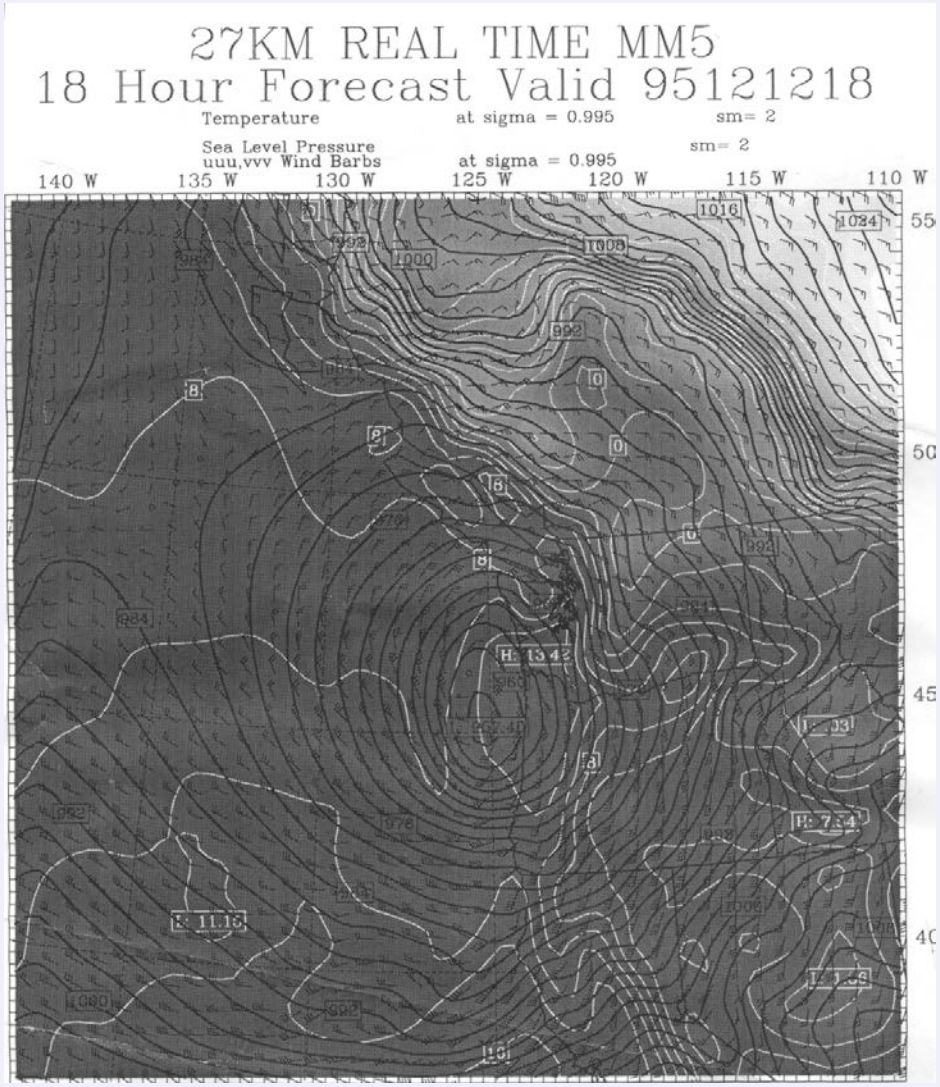
FIG. 7. Mesoscale analyses for (a) 1500 UTC, (b) 1600 UTC, (c) 1700 UTC, (d) 1800 UTC, (e) 1900 UTC, and (f) 2000 UTC 20 January 1993. Contour interval is 2 mb.

Steenburgh and Mass, MWR, 2000

And then another major storm and a highly skillful forecast

December 12, 1995

An Excellent Forecast



And the media went wild!

Dec. 11

Brace yourself for winds

80-mph gusts are possible

SEATTLE TIMES STAFF

The windstorm hitting Western Washington today could rival the ferocity of a Columbus Day 1962 storm that killed eight people, closed hundreds of roads, and caused widespread power outages and millions of dollars in damage, forecasters say.

Gusts of 70 to 80 mph were expected in the Puget Sound area, with the peak of the storm forecast to hit the Seattle area about 5 p.m. High winds are expected to continue into the night.

The low-pressure system built early today off the Oregon Coast, where residents braced for winds as high as 100 mph.

Along the Washington Coast, emergency crews prepared to deal with the possibility of widespread damage. Many schools in Grays Harbor County planned to send students

INSIDE

An unusual storm

Weather experts say several factors make today's low-pressure system off the Washington Coast unusual and are expected to produce extremely high winds in the Puget Sound area this evening.

A 18

A different reaction by society

- Based on the forecasts, Boeing and other major employers sent their staff home early.
- The NWS forecasts had the correct timing--within hours.
- Seattle and Portland NWS forecasters won a NWA Award for their predictions.

And another great success: the December 15, 2006 Chanukah Eve Storm… and many more

In parallel to work on the east coast, there was extensive research to understand explosive cyclogenesis over the eastern Pacific

A Case Study of Explosive Cyclogenesis in the Eastern Pacific

RICHARD J. REED AND MARK D. ALBRIGHT

Department of Atmospheric Sciences, University of Washington, Seattle, WA 98195

(Manuscript received 7 October 1985, in final form 25 April 1986)

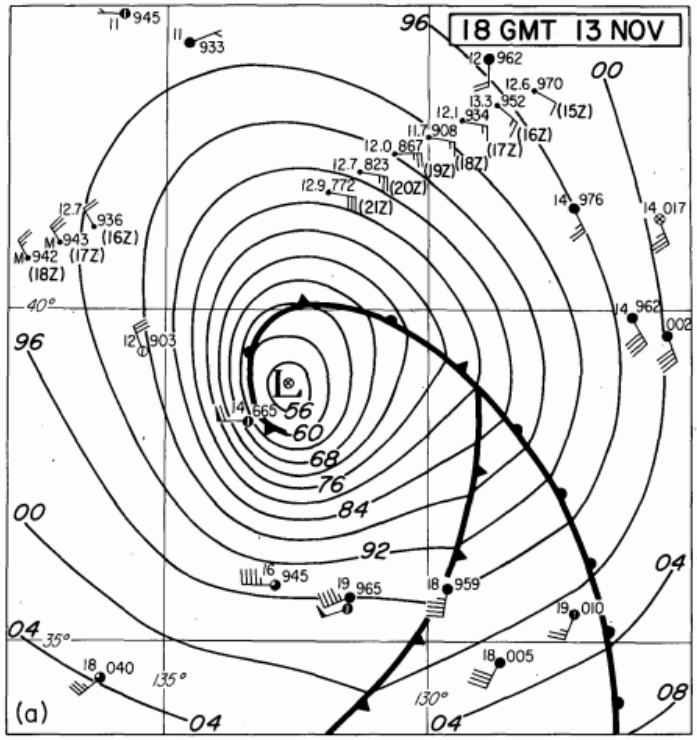
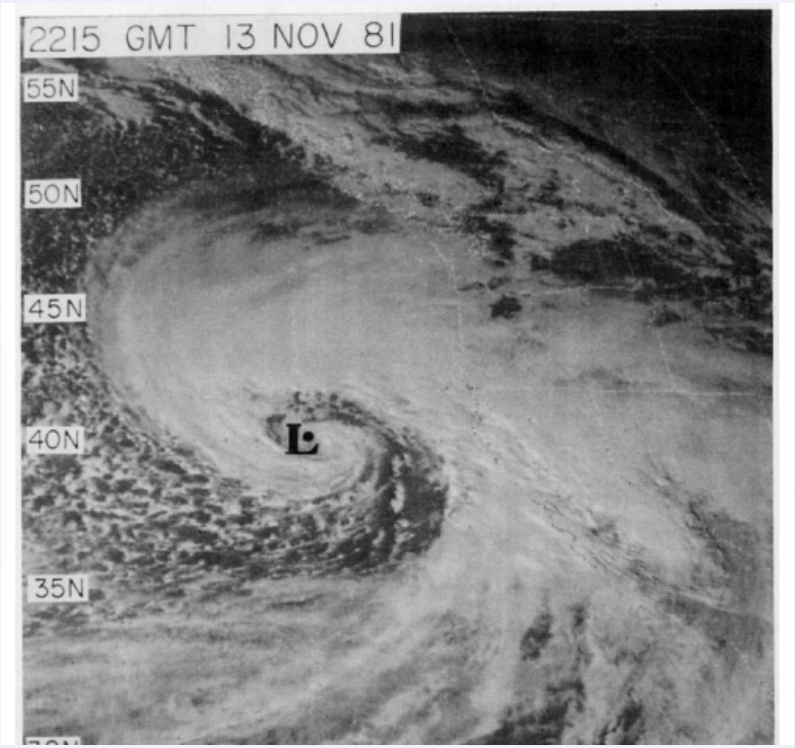


FIG. 11. Surface isobaric and frontal analyses: (a) 1800 GMT 13 November and (b) 0000 GMT 14 November 1981. Dashed lines in (b) are isotherms (°C) and shading denotes intermediate temperatures (13°–15°C). Small circles indicate actual or displaced buoy positions. Times of displaced observations are given in parentheses. See text for further explanation.



Numerical Simulation of an Explosively Deepening Cyclone in the Eastern Pacific

YING-HWA KUO

National Center for Atmospheric Research, Boulder, Colorado*

RICHARD J. REED

Department of Atmospheric Sciences, University of Washington, Seattle, Washington

(Manuscript received 15 December 1987, in final form 26 April 1988)

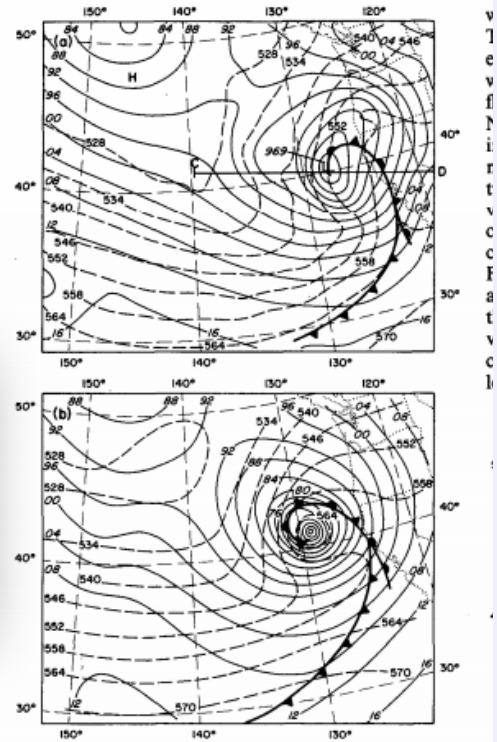


FIG. 4. Sea level pressure (solid) and 1000–500 mb thickness (dashed) for (a) 24 hour forecast for control experiment verifying at 0000 UTC 14 November with fronts subjectively added, and (b) the subjective analysis at the same time reproduced from Reed and Albright (1986). Line of later cross sections indicated by CD.

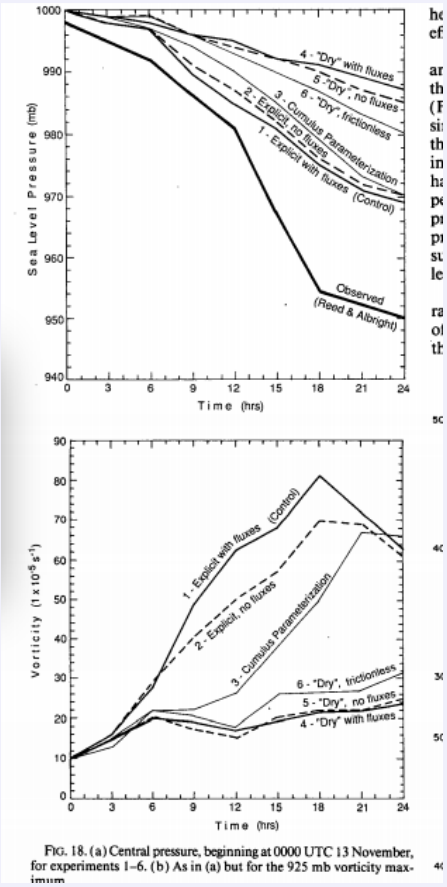


FIG. 18. (a) Central pressure, beginning at 0000 UTC 13 November, for experiments 1–6. (b) As in (a) but for the 925 mb vorticity maximum

Field Programs (COAST) and Modeling During the 1990s and Later Revealed Structures Similar to the Keyser-Shapiro Model Off the Pacific Coast

- Strongest winds in the bent-back trough
- But no evidence of evaporatively forced "sting jets"

Chanukah Eve Storm Dec. 2006

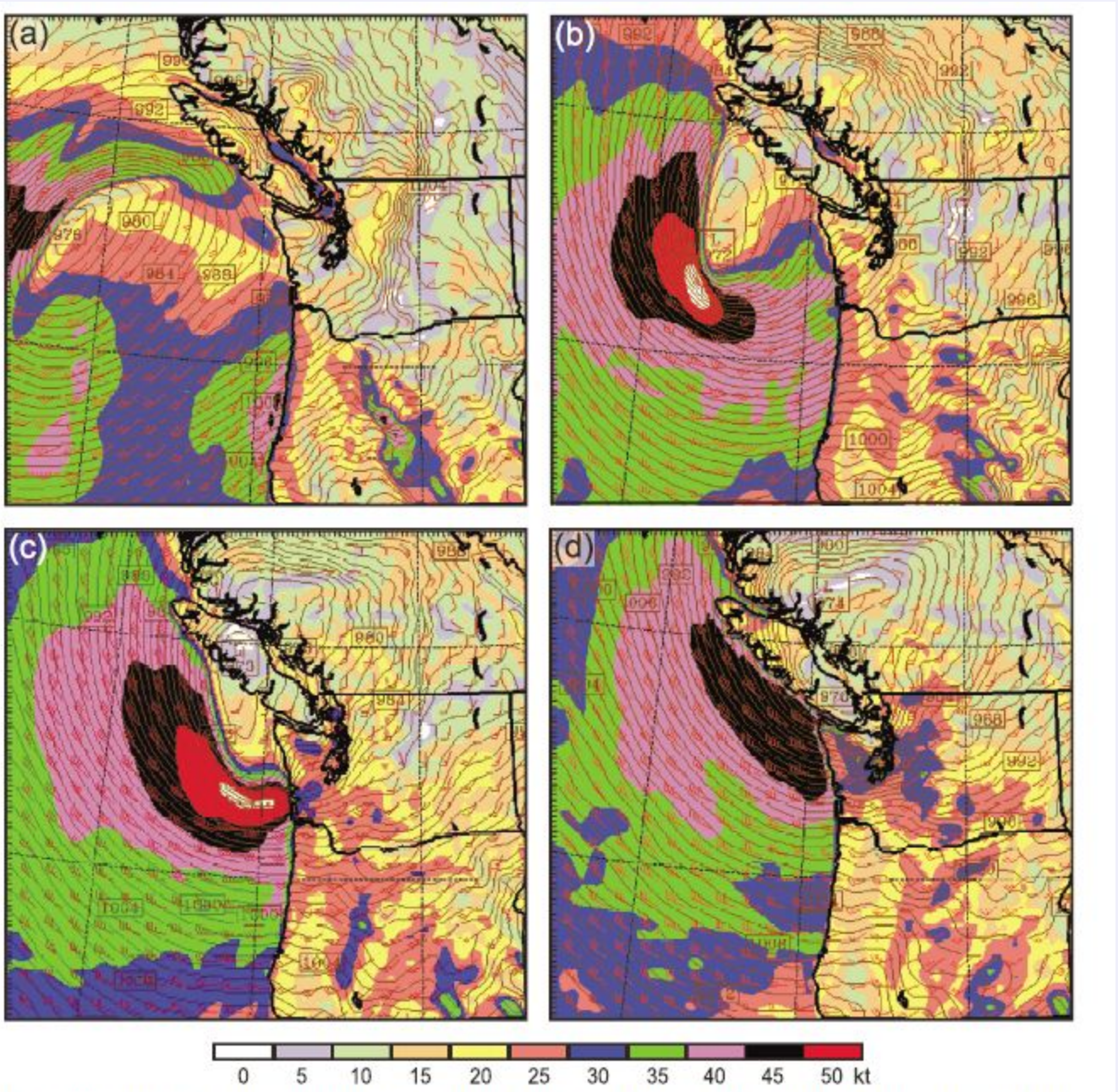
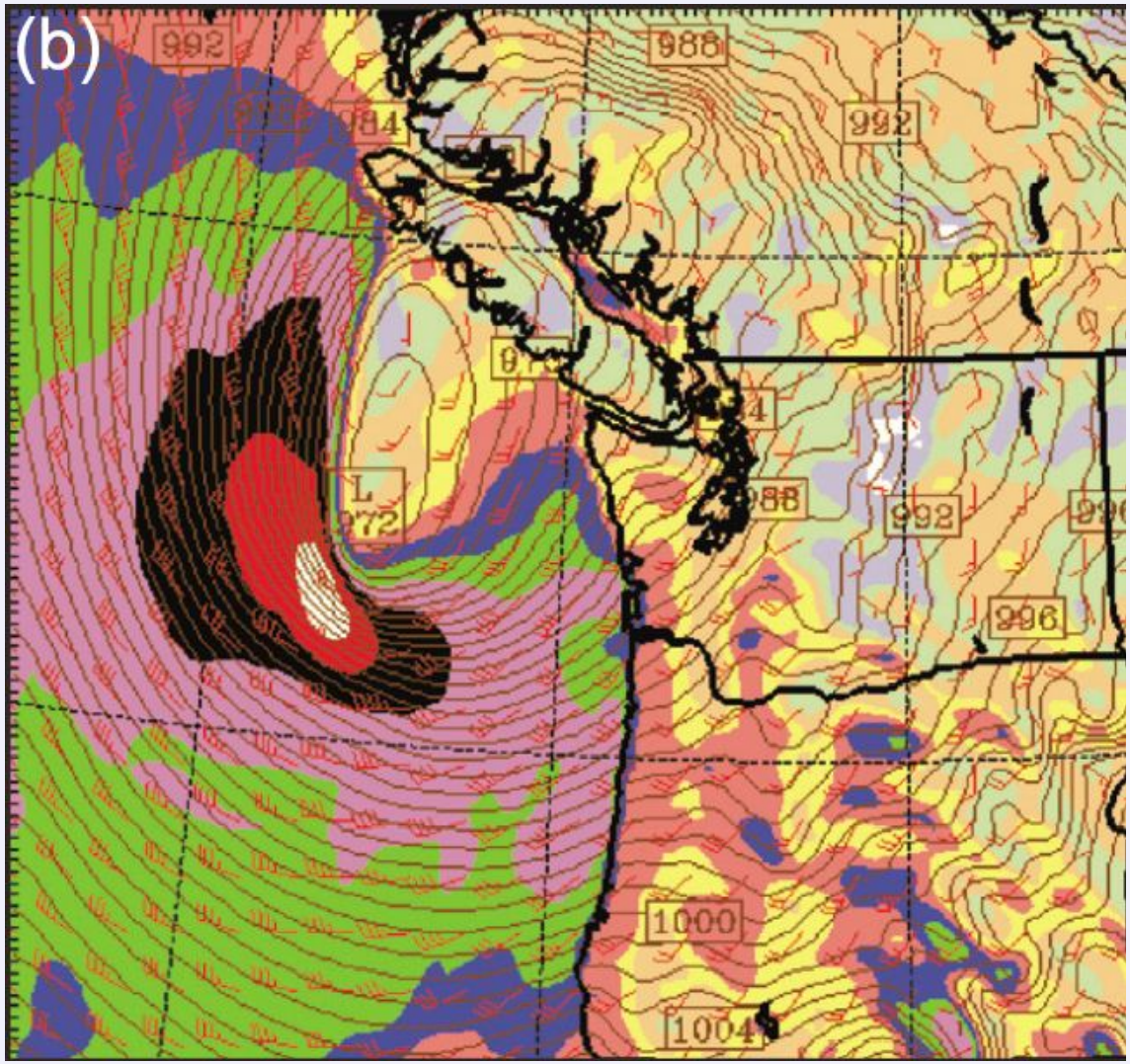
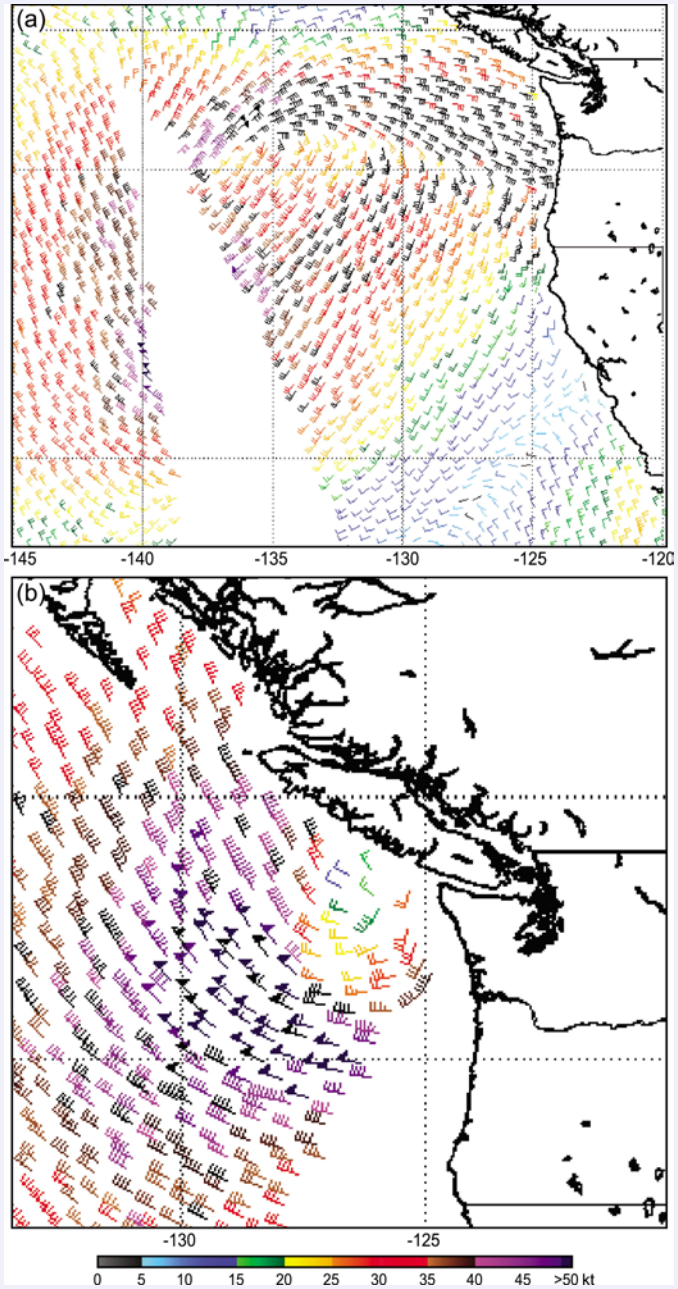


FIG. 12. MM5 10-m wind-speed forecasts (kt) valid at (a) 2100 UTC 14 Dec, (b) 0300 UTC 15 Dec, (c) 0600 UTC 15 Dec, and (d) 0900 UTC 15 Dec 2006. SLP isobars (hPa) are shown in solid lines, 1-hPa contour interval.

Strongest Winds With Back-Bent



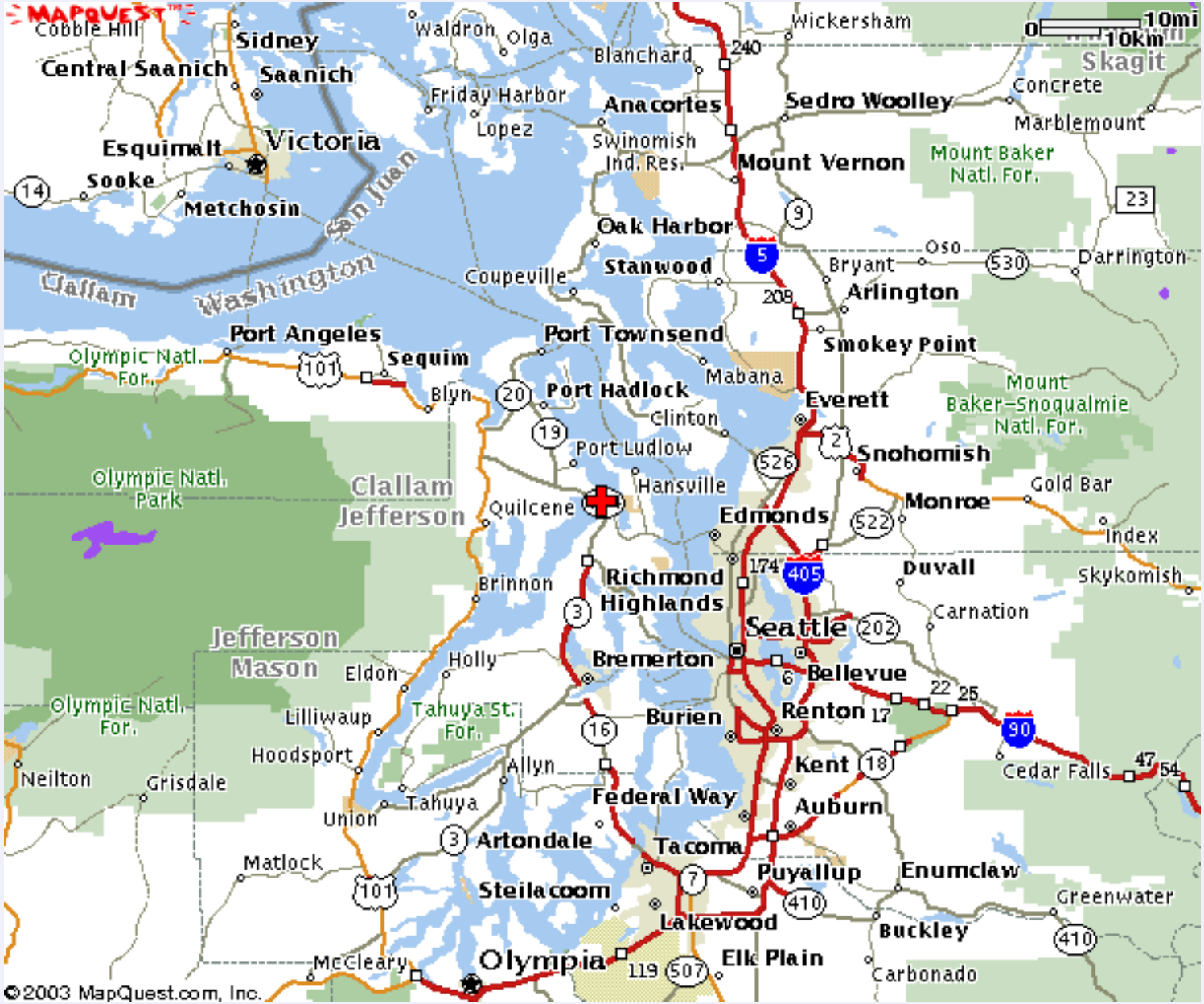
Scatterometer Winds for the Chanukah Eve Storm Dec. 2006



The Challenges of Pacific Cyclones Also Include Their Interactions with the Substantial Terrain of the West Coast

- This became very evident in February 1979 during the Hood Canal Storm.
- Winds were predicted to reach 40-50 kt, but locally gusted to 120 mph, destroying a 100-million dollar bridge.

Feb. 13, 1979: Winds over 100 kts destroyed the Hood Canal Bridge
Cost to replace: over 100 million dollars


MAPQUEST
0 10mi
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Cobble Hill
Sidney
Central Saanich
Saanich
Victoria
Esquimalt
Sooke
Metchosin
Waldron
Olga
Friday Harbor
Lopez
San Juan
Clallam
Washington
Blanchard
Anacortes
Swinomish Ind. Res.
Wickersham
Skagit
Concrete
Sedro Woolley
Marblemount
Mount Vernon
Mount Baker Natl. For.
Oak Harbor
Stanwood
Coupeville
Oso
Bryant
Darrington
Arlington
Smokey Point
Port Angeles
Olympic Natl. For.
Sequim
Port Townsend
Mabana
Blyn
Port Hadlock
Clinton
Everett
Mount Baker-Snoqualmie Natl. For.
Port Ludlow
Snohomish
Olympic Natl. Park
Clallam
Jefferson
Hansville
Quilcene
Gold Bar
Monroe
Edmonds
Index
Brinnon
Richmond Highlands
Duvall
Skykomish
Carnation
Seattle
Jefferson
Mason
Eldon
Holly
Bremerton
Bellevue
Olympic Natl. For.
Lilliwaup
Tahuya St. For.
Burien
Renton
Hoodsport
Allyn
Kent
Cedar Falls
Neilton
Grisdale
Tahuya
Federal Way
Auburn
Union
Artondale
Tacoma
Matlock
Puyallup
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Steilacoom
Greenwater
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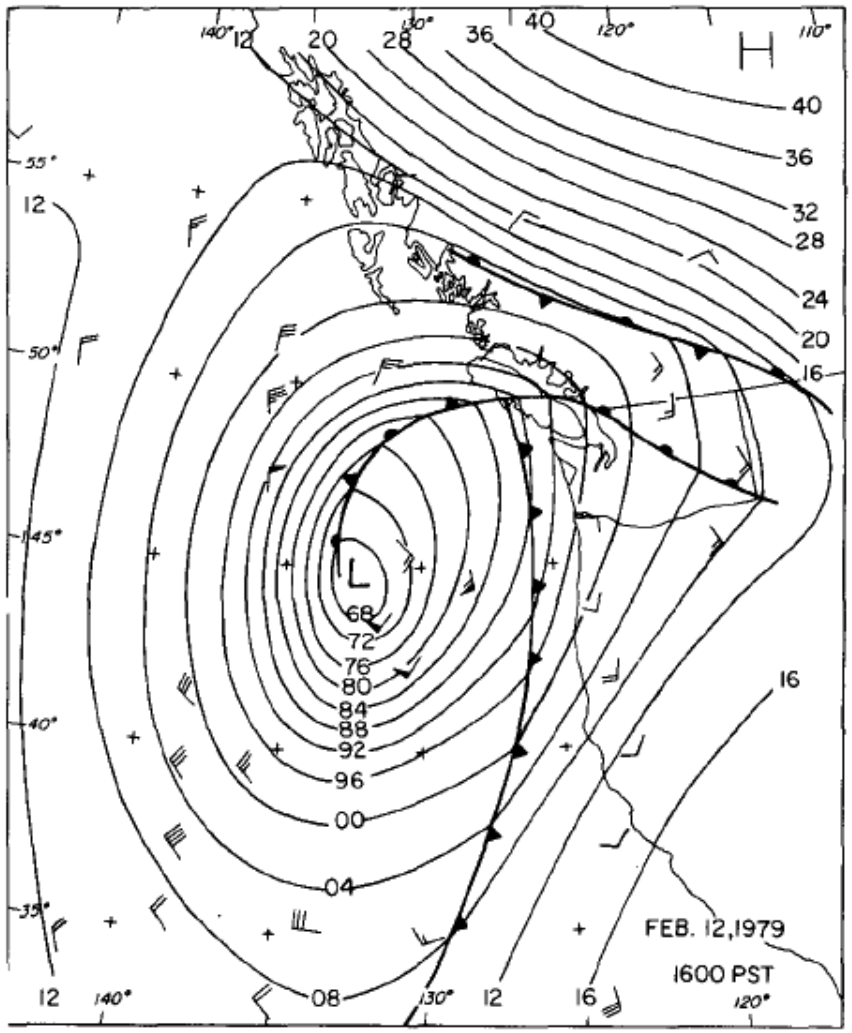


FIG. 4. Surface map for 1600 PST 12 February 1979. Winds are in knots. (A full barb represents 10 kt, a pennant 50 kt.)

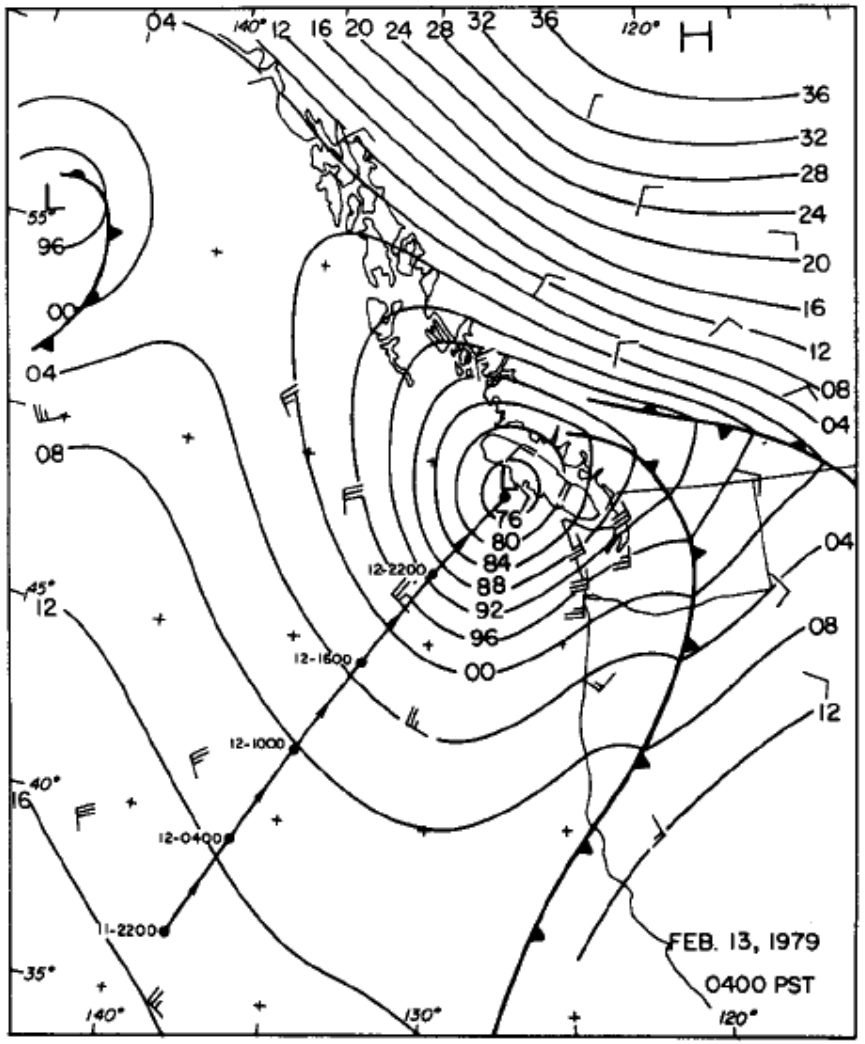
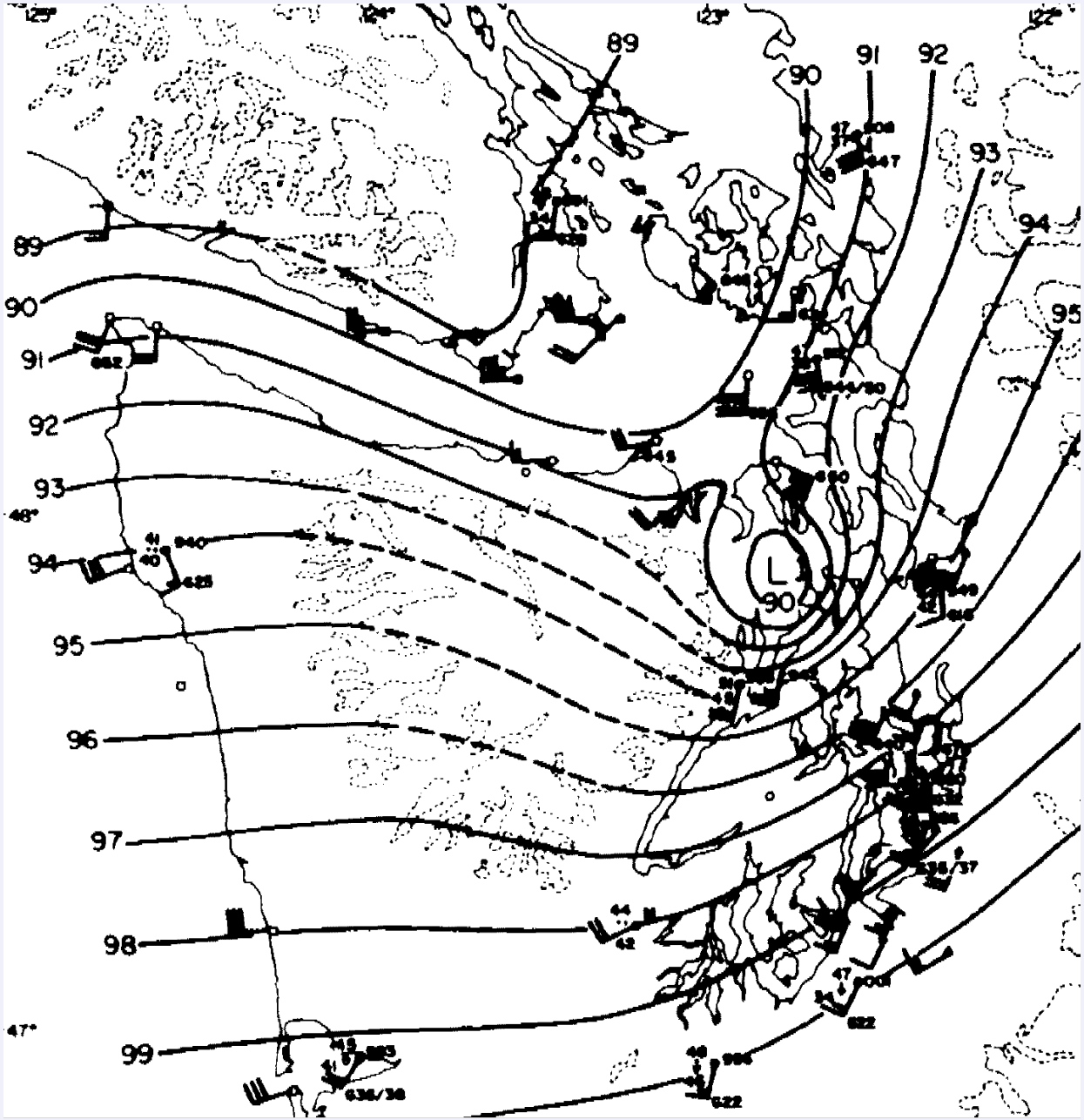


FIG. 6. Surface map for 0400 PST 13 February 1979. Storm track is indicated by arrows. Dots give position of center at indicated times.

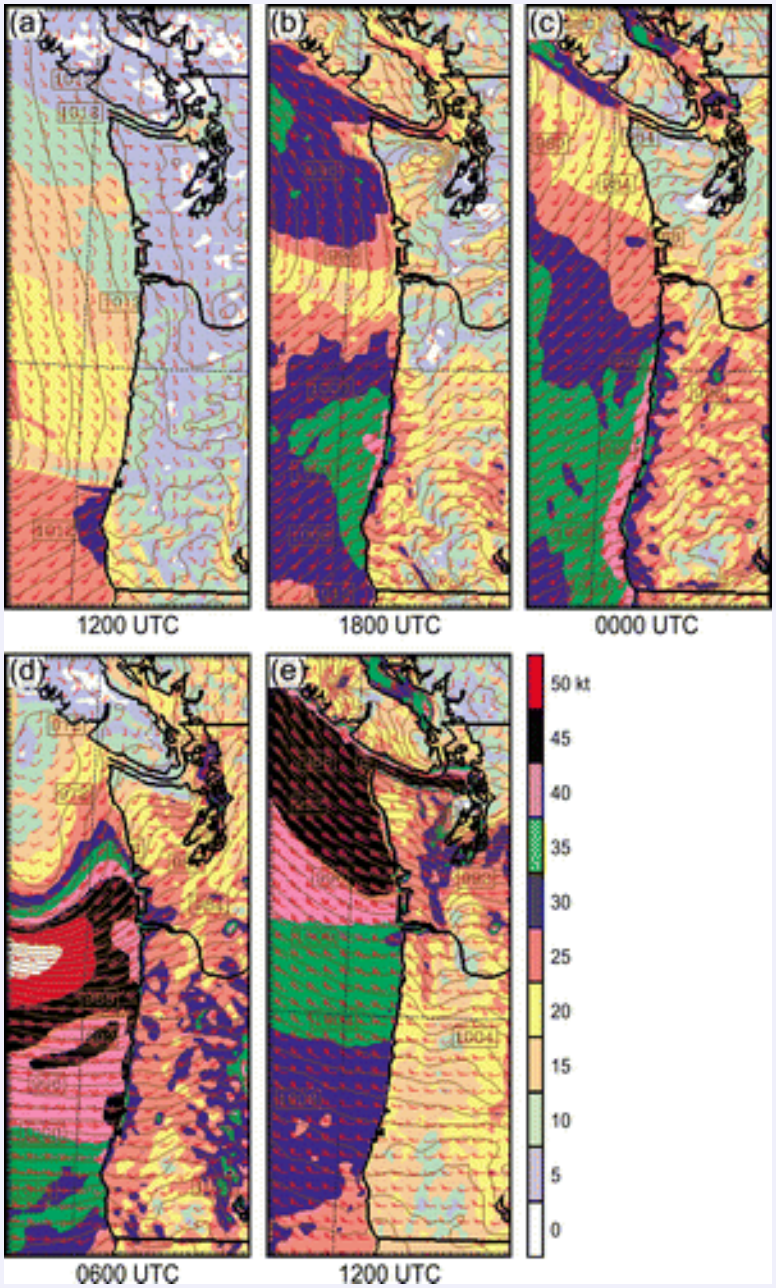
But why localized 120 knot winds?

Professor Richard Reed found an intense lee-side mesolow

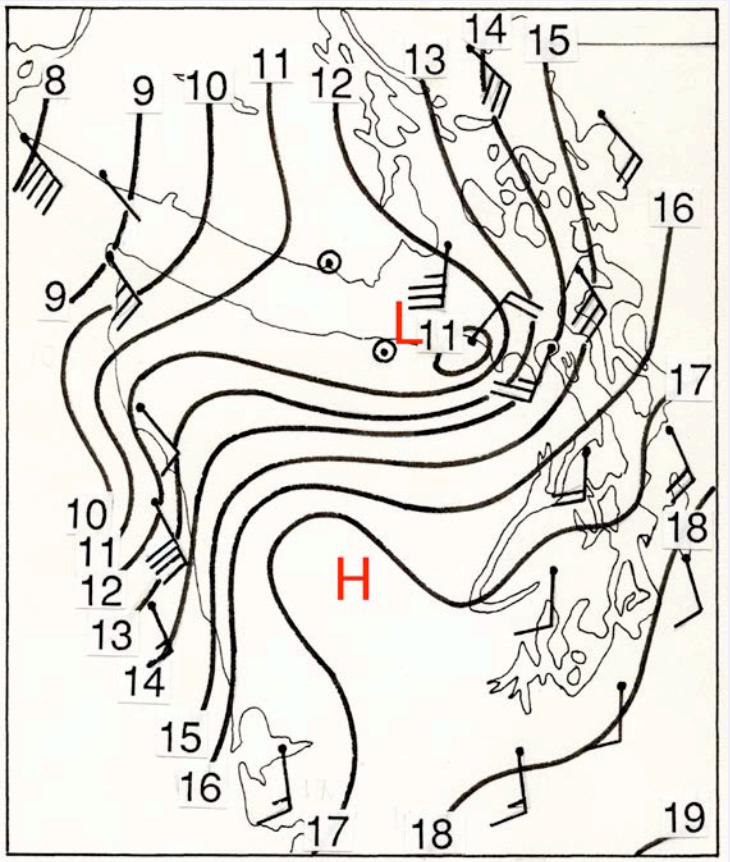


Do cyclone/terrain interactions produce stronger winds near coastal terrain?

Yes, but only when the stability is high

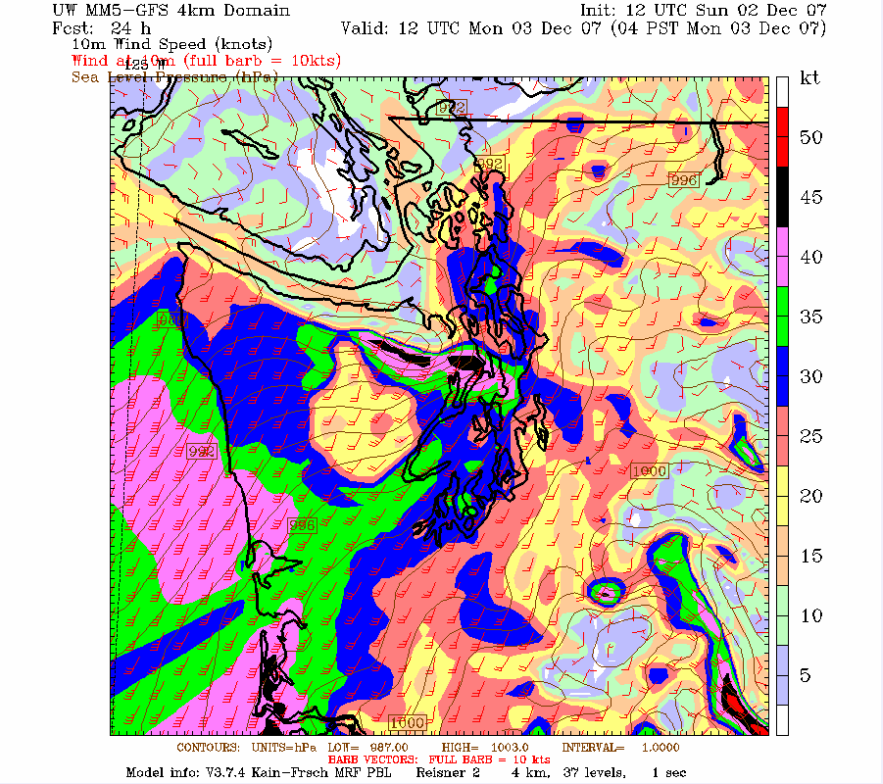


And certain locations are favored for cyclone/terrain wind enhancement



Mesoscale Models

High-resolution mesoscale models can get the terrain effects correct much of the time.



A Lot to Be Proud Of…

- Global models (e.g., GFS, ECMWF) are now providing excellent guidance (1-3 days out) for nearly all major cyclones. Often substantial skill 4-7 days ahead.
- We now possess an extraordinarily better understanding of the mesoscale structures of these storms and how they are modified by West Coast terrain
- High-resolution models appear capable of skillfully predicting many terrain/cyclone interactions.

The End